This is all that is really necessary, for when the lists are once sanctioned observers who have the opportunity can start work immediately, knowing that *not one single observation will thenceforward be wasted*, and that the sooner they commence the more valuable will their results eventually become.

Of course an international committee ought, if possible, to be appointed, to meet occasionally and see that there are no gaps; and if they have opportunities of obtaining funds for printing so much the better; but this, though desirable, is not essential. Let us have the scheme discussed, and, if considered advisable, have the catalogues prepared forthwith.

Perth Observatory, Western Australia:
1905 *July* 4.

On the Secular Accelerations of the Moon's Longitude and Node.

By P. H. Cowell.

In this paper I determine the secular accelerations of the Moon's longitude and node from the solar eclipses of the years −1062, −762, −647, −430, and +197.

The historical references are as follows:—

1. Inscription at Babylon:

"On the 26th day of the month Sivan, in the 7th year, the day was turned into night, and fire in the midst of heaven."

This inscription was communicated to me by Mr. L. W. King, of the Department of Egyptian and Assyrian Antiquities, British Museum, the translator, early in September. I may add that a few days previously I had shown to Professor Newcomb, in MS., the corrections that I had deduced from the other four eclipses mentioned in this paper. It turned out that this eclipse supported the corrections deduced from the other four.

2. Inscription at Nineveh:

"In the month Sivan the Sun underwent an eclipse."

3. Archilochus, 74:

Ζεὺς πατὴρ Ὀλυμπίων
ἐκ μεσημβρίης ἔθηκε νύκτ' ἀποκρύψας φάος
ἡλίου λάμποντος.

4. Thucydides, II. 28:

Τοῦ δ' αὐτοῦ θέρους νουμηνίᾳ κατὰ σελήνην, ὥσπερ καὶ μόνον δοκεῖ εἶναι γίγνεσθαι δυνατόν, ὁ ἥλιος ἐξέλιπε μετὰ μεσημβρίαν καὶ πάλιν ἀνεπληρώθη, γενόμενος μηνοειδὴς καὶ ἀστέρων τινῶν ἐκφανέντων.

5. Tertullian ad Scapulam, c. 3:

"Nam et sol ille in conventu Uticensi, extincto pæne lumine, adeo portentum fuit, ut non potuerit ex ordinario deliquio hoc pati, positus in suo hypsomate et domicilio. Habetis astrologos."

The method is as follows :—

Let T be an approximate time reckoned in Julian centuries from 1800 January 0·0 G.M.T.

Let V, U, p be the Moon's tabular longitude and latitude and parallax ; let $\mathrm{V}+\Delta\mathrm{V}$, $\mathrm{U}+\Delta\mathrm{U}$ be the Moon's true longitude and latitude.

Let V', p' be the Sun's tabular longitude and parallax.

Let v', u' be the parallax in longitude and latitude calculated for the Sun's place with the negative parallax $p'-p$.

Let $\mathrm{T}+t$ be the time of apparent conjunction in longitude.

For convenience t is measured in units of one-millionth part of a Julian century, or about fifty-three minutes.

Thus by definition of t

$$\mathrm{V}-\mathrm{V}'-v'+t\frac{d}{dt}(\mathrm{V}-\mathrm{V}'-v')+\Delta\mathrm{V}=0$$

If the place chosen for calculation is on the central line, then the apparent latitudes must be equal ; or

$$\mathrm{U}-u'+t\frac{d}{dt}(\mathrm{U}-u')+\Delta\mathrm{U}=0$$

Eliminate t ; put

$$\frac{d}{dt}(\mathrm{U}-u')=k\frac{d}{dt}(\mathrm{V}-\mathrm{V}'-v')$$

then

$$\Delta\mathrm{U}-k\Delta\mathrm{V}=k(\mathrm{V}-\mathrm{V}'-v')-(\mathrm{U}-u')$$

This is the equation of condition for centrality. k is usually a small fraction, but its maximum value is $\frac{1}{3}$. It will be observed that $\Delta\mathrm{V}$ has k as a factor. The central line runs eastward ; an alteration of V alters the time at which the Moon is interposed between the Earth and the Sun, and therefore the face of the Earth turned to the Sun is altered by diurnal rotation. This course alone shifts every point on the central line due east or west ; and the two positions of the central line are not very widely separated, except that one line overlaps the other at its west end and the other at its east.

If we assume that the parts of $\Delta\mathrm{V}$, $\Delta\mathrm{U}$ that arise from corrections to the secular accelerations outweigh in importance all other corrections required by the tables (this is obviously the case if the tabular secular accelerations are one second in error), we may put

$$\Delta\mathrm{U}=\pm 0{\cdot}0895\,\mathrm{T}^2 s_{\mathrm{F}} \qquad \Delta\mathrm{V}=\mathrm{T}^2 s_{\mathrm{L}}$$

where s_{F}, s_{L} are the corrections required by the secular accelerations of the argument of latitude and mean longitude.

The Hansen-Newcomb tables of the Moon now in use in the *Nautical Almanac* are based upon the following formulæ :

$$
\begin{aligned}
g &= 110^\circ\ 19'\ 32''\!\cdot\!50 + 171791\ 5807''\!\cdot\!98\mathrm{T} + 45''\!\cdot\!675\mathrm{T}^2 + 0''\!\cdot\!050073\mathrm{T}^3 \\
\omega &= 192\ \ 7\ 21\cdot91 + \ \ 2161\ 1522\cdot07\mathrm{T} - 44\cdot323\mathrm{T}^2 - 0\cdot043759\mathrm{T}^3 \\
-\Omega &= 326\ 43\ 28\cdot85 + \ \ \ 696\ 2939\cdot61\mathrm{T} - \ 8\cdot189\mathrm{T}^2 - 0\cdot007159\mathrm{T}^3
\end{aligned}
$$

The Newcomb tables of the Sun now in use in the *Nautical Almanac* are based upon the formulæ

$$
\begin{aligned}
\mathrm{L}' &= 279^\circ\ 54'\ 28''\!\cdot\!75 + 12960\ 2765'\!\cdot\!95\mathrm{T} + 1''\!\cdot\!089\mathrm{T}^2 \\
\pi' &= 279\ 29\ 47\cdot26 + \qquad 6185\cdot80\mathrm{T} + 1\cdot590\mathrm{T}^2 + 0''\!\cdot\!012\mathrm{T}^3
\end{aligned}
$$

where I have transferred the epoch to 1800 Jan. 0·0 G.M.T.

The formulæ employed in the present calculations are

$$
\begin{aligned}
g &= 110^\circ\ 19'\ 38'' + 171791\ 5794''\mathrm{T} + 44''\!\cdot\!4\mathrm{T}^2 + 0''\!\cdot\!050\mathrm{T}^3 \\
\omega &= 192\ \ 7\ 25 + \ \ 2161\ 1516\mathrm{T} - 40\cdot0\mathrm{T}^2 - 0\cdot044\mathrm{T}^3 \\
-\Omega &= 326\ 43\ 39 + \ \ \ 696\ 2921\mathrm{T} - \ 3\cdot7\mathrm{T}^2 - 0\cdot007\mathrm{T} \\
\mathrm{L}' &= 279\ 54\ 29 + 12960\ 2766\mathrm{T} + \ 1\cdot1\mathrm{T}^2 \\
\pi' &= 279\ 29\ 47 + \qquad 6186\mathrm{T} + \ 1\cdot6\mathrm{T}^2 + 0\cdot012\mathrm{T}^3
\end{aligned}
$$

The solar elements L′, π′, and the cube terms of the lunar elements have been modified only to the extent of omitting a few insignificant figures. The other alterations are

$$
\begin{aligned}
\Delta g &= +\ 5''\!\cdot\!50 - 13''\!\cdot\!98\mathrm{T} - 1''\!\cdot\!275\mathrm{T}^2 \\
\Delta\omega &= +\ 3\cdot09 - \ 6\cdot07\mathrm{T} + 4\cdot323\mathrm{T}^2 \\
-\Delta\Omega &= +10\cdot15 - 18\cdot61\mathrm{T} + 4\cdot489\mathrm{T}^2
\end{aligned}
$$

whence

$$
\begin{aligned}
\Delta\mathrm{L} &= -1''\!\cdot\!56 - \ 1''\!\cdot\!44\mathrm{T} - 1''\!\cdot\!441\mathrm{T}^2 \\
\Delta\varpi &= -\ 7\cdot06 + 12\cdot54\mathrm{T} - 0\cdot166\mathrm{T}^2 \\
\Delta\mathrm{F} &= +8\cdot59 - 20\cdot05\mathrm{T} + 3\cdot048\mathrm{T}^2
\end{aligned}
$$

The constants and centennial motions are approximately those deduced by myself from modern observations. The secular accelerations of L and F are approximately those deduced in the present investigation, which has been rewritten with the corrections introduced. The secular term of the perigee is hardly altered from Hansen. I decided not to introduce into it an empirical correction of $+3''$ with a possible error of $\pm 7''$, which I deduced in *Monthly Notices*, lxv. p. 275, from the observations 1750–1901.

The mean motions employed are probably correct to within $5''$. An error of $5''$ in any mean motion can be approximately balanced by an alteration $0''\!\cdot\!3$ in the secular term

No correction for the position of the perigee is introduced into the equations of condition. If all the eclipses considered occurred at perigee, an error in the perigee could be balanced by an alteration of the mean longitude of one-ninth the amount. With the actual eclipses employed, the residuals could be diminished by a properly chosen correction to the perigee, but such a correction would not be entitled to any weight.

The secular acceleration of the mean sidereal motion employed in my tabular places is $+7''\cdot 0$.

The inequalities of the Moon are calculated from the following formulæ :

$$
\begin{aligned}
V-L = {} & 22640'' \sin g \\
& + 4586 \sin(-g+2D) \\
& + 2370 \sin 2D \\
& + 769 \sin 2g \\
& + 669 \sin -g' \\
& + 412 \sin -2F \\
& + 212 \sin(-2g+2D) \\
& + 206 \sin(-g-g'+2D) \\
& + 192 \sin(g+2D) \\
& + 165 \sin(-g'+2D) \\
& + 148 \sin(g-g') \\
& + 125 \sin -D \\
& + 110 \sin(-g-g') \\
& + 55 \sin(-2F+2D) \\
& + 45 \sin(-g-2F) \\
& + 40 \sin(g-2F) \\
& + 38 \sin(-g+4D) \\
& + 36 \sin 3g \\
& + 31 \sin(-2g+4D) \\
& + 29 \sin(g-g'-2D) \\
& + 24 \sin(-g'-2D)
\end{aligned}
$$

$$
\begin{aligned}
U = {} & 18461'' \sin F \\
& + 1010 \sin(g+F) \\
& + 1000 \sin(g-F) \\
& + 624 \sin(-F+2D) \\
& + 199 \sin(-g+F+2D) \\
& + 167 \sin(-g-F+2D) \\
& + 117 \sin(F+2D) \\
& + 62 \sin(2g+F) \\
& + 33 \sin(g-F+2D) \\
& + 32 \sin(2g-F) \\
& + 30 \sin(-g'-F+2D) \\
& + 16 \sin(-2g-F+2D) \\
& + 15 \sin(g+F+2D) \\
& + 12 \sin(-g'+F-2D)
\end{aligned}
$$

$$
\begin{aligned}
p-p' &= 3414''+187''\cos g+34''\cos(-g+2D) \\
&\qquad +28''\cos 2D+10''\cos 2g \\
\frac{d}{dt}(V-V') &= 1632''+227''\cos g \qquad +13''\cos 2g-5\cos g' \\
\pm\frac{dU}{dt} &= 163''+\ 20''\cos g \qquad +\ 2''\cos 2g
\end{aligned}
$$

The last two expressions have been reduced by putting $D=0$,

$2F = 0$ in the accurate expressions. For the Sun the formula used is

$$V' - L' = e_1' \sin g' + e_2' \sin 2g'$$

where
$$e_1' = 6927''\cdot2 - 17''\cdot14T - 0''\cdot052T^2$$
$$e_2' = 72\cdot7 - 0\cdot36T$$

The corrections for parallax are calculated by the formulæ

$$v' = (p-p') \sin\lambda \sin\varepsilon \cos V' + (p-p') \cos\lambda \cos^2\frac{\varepsilon}{2} \sin(h-V') - (p-p') \cos\lambda \sin^2\frac{\varepsilon}{2} \sin(h+V')$$

$$\frac{dv'}{dt} = 0\cdot2295 \times (p-p') \cos\lambda \cos^2\frac{\varepsilon}{2} \cos(h-V') - 0\cdot2307 \times (p-p') \cos\lambda \sin^2\frac{\varepsilon}{2} \cos(h+V')$$

$$u' = (p-p') \sin\lambda \cos\varepsilon - (p-p') \cos\lambda \sin\varepsilon \sin h$$

$$\frac{du'}{dt} = -0\cdot2301 \times (p-p') \cos\lambda \sin\varepsilon \cos h$$

where ε is the obliquity of the ecliptic

$$\varepsilon = 23^\circ\ 27'\ 55''\cdot1 - 46''\cdot83T$$
$$\sin\varepsilon = 0\cdot4023\ 5 - 0\cdot0002\ 1(T+20)$$
$$\cos\varepsilon = 0\cdot9154\ 9 + 0\cdot0000\ 9(T+20)$$

and λ is the latitude of the place of calculation and h the local sidereal time.

Owing to their rapid curvature the parallactic corrections for $T+t$ can only be calculated by the formula given, if the correction t is small.

The numerical work is given below. The calculations are extended to the eclipse of -1069 June 20, in order to show that the eclipse of this date was not total at Babylon. I should add that Mr. King would have much preferred a date in June being assigned to his eclipse instead of a date in July, owing to the reference to the month Sivan.

Ref. No.	T.	Place.	Authority.	Lat. N.	Long. N.
				° ′	° ′
0	−28·6850167	Babylon	...	+32 26	+44 13
1	−28·6138889	,,	Inscription	+32 26	+44 13
2	−25·6151436	Nineveh	,,	+36 24	+43 0
3	−24·4670532	Thasos	Archilochus	+40 40	+24 40
4	−22·2937936	Athens	Thucydides	+37 56	+23 38
5	−16·0254612	Utica	Tertullian	+37 10	+10 0

Ref. No.	Local Mean Time Corresponding to T. d h m	T^2.	T^3.	0·0895 T^3.	g. ° ′ ″
0	−1069 June 19 28 18·5	822·83	−23603	74	303 41 32
1	−1062 July 30 19 56·3	818·75	−23428	73	45 44 51
2	− 762 June 14 23 59·2	656·14	−16807	59	41 35 15
3	− 647 April 5 22 48·5	598·64	−14647	54	348 18 21
4	− 430 Aug. 3 6 6·3	497·01	−11080	45	264 2 38
5	+ 197 June 3 1 22·7	256·82	− 4116	23	262 4 33

Ref. No.	ω. ° ′ ″	$-\Omega$. ° ′ ″	L′. ° ′ ″	π'. ° ′ ″	L. ° ′ ″
0	61 24 33	284 57 15	77 31 7	230 29 35	80 8 50
1	128 26 48	62 31 46	118 10 23	230 36 50	111 39 53
2	132 14 13	102 41 28	75 15 29	235 43 0	71 8 0
3	185 3 51	163 19 9	7 22 37	237 40 16	10 3 3
4	272 39 36	46 48 55	126 21 40	241 22 20	129 53 19
5	105 17 21	290 54 38	71 4 14	252 3 35	76 27 16

Ref. No.	V−L.	V′−L′.	V−V′.	U.	$\frac{d}{dt}$(V−V′).	$\frac{dU}{dt}$	$p-p'$.
0	−14907″	−3285″	−2159″	+ 231″	+1757″	+173″	3558″
1	+13676	−6758	−2996	+ 718	+1792	−177	3589
2	+12442	−2399	− 8	+ 875	+1809	−178	3605
3	− 4176	+5548	− 98	+2375	+1869	−185	3667
4	−17107	−6538	+2130	+2577	+1597	−159	3405
5	−17951	+ 121	+1310	+ 776	+1593	+158	3394

Ref. No.	h=Local Sid. Time. ° ′	v'.	u'.
0	37 9	+179−1827−117=−1765″	+1745− 733=+1012′
1	57 14	−345−2488− 15=−2848	+1761−1029=+ 732
2	75 3	+229+ 23− 62=+ 190	+1957−1131=+ 826
3	349 31	+952− 885+ 3=+ 70	+2187+ 204=+2391
4	217 57	−478+2567+ 34=+2123	+1916+ 665=+2581
5	91 45	+267+ 914− 34=+1147	+1877−1086=+ 791

Ref. No.	$\frac{dv'}{dt}$.	$\frac{du'}{dt}$.	$\frac{d}{dt}$(V−V′−v') =denom. of k.	$\frac{d}{dt}$(U−u') =num. of k.	k
0	+510+12=+522″	−222″	+1235″	+395″	+·320
1	+342+30=+372	−153	+1420	− 24	−·017
2	+638+24=+662	− 69	+1147	−109	−·095
3	+576−27=+549	−254	+1320	+ 69	+·052
4	− 35−25=− 60	+196	+1537	−355	−·231
5	+557+25=+582	+ 8	+1011	+150	+·148

Ref. No.	$-kT^2$.	$V-V'-v'$.	t.	$k(V-V'-v')-(U-u')$.
0	−263	−394	+0·3	+655″
1	+ 13	−148	+0·1	+ 17
2	+ 62	−198	+0·2	− 30
3	− 31	−168	+0·1	+ 8
4	+115	+ 7	0·0	+ 2
5	− 38	+163	−0·2	+ 39

The large value in the first line of the last column shows that about one-third of the Sun was visible at Babylon at the maximum phase of the eclipse of −1069 June 20.

The equations of condition resulting from the other five eclipses are :

$$
\begin{aligned}
-73\,s_F + 13\,s_L &= +17'' \\
-59\,s_F + 62\,s_L &= -30 \\
-54\,s_F - 31\,s_L &= +\ 8 \\
-45\,s_F + 115\,s_L &= +\ 2 \\
+23\,s_F - 38\,s_L &= +39
\end{aligned}
$$

In some cases the right-hand sides are less than the difference of semi-diameters. A least-squares solution gives $s_L = -0''\cdot18$, $s_F = -0''\cdot05$; but these quantities are less than the probable errors.

The eclipse of Agathocles −309 Aug. 15 is central about fifty miles north of Syracuse. The figures are not reproduced here.

The equation of condition for the eclipse of −1062 shows that, with Hansen's position of the node, totality, even in the neighbourhood of Babylon, is impossible without a large increase of the secular acceleration.

On the Value of Ancient Solar Eclipses. By P. H. Cowell.

In *Ast. Nach.*, No. 3682, Professor Newcomb argues against the corrections to the three lunar elements, viz. the mean longitude and the longitude of perigee and node, based by Oppolzer and Ginzel on ancient solar eclipses. These corrections, as Professor Newcomb points out, are incompatible with modern observations and with theory, and I, like Professor Newcomb, believe them to be erroneous.

In the opening paragraphs of the paper referred to, Professor Newcomb lays down that "no attempt should be made to determine the motion either of the perigee or node from ancient eclipses" on the ground that their centennial motions have been settled by the accordance of modern observation with theory to within limits of error that would have no "appreciable effect on the paths of ancient eclipses." Professor Newcomb, however, ignores the possibility of errors in the secular variations. Now